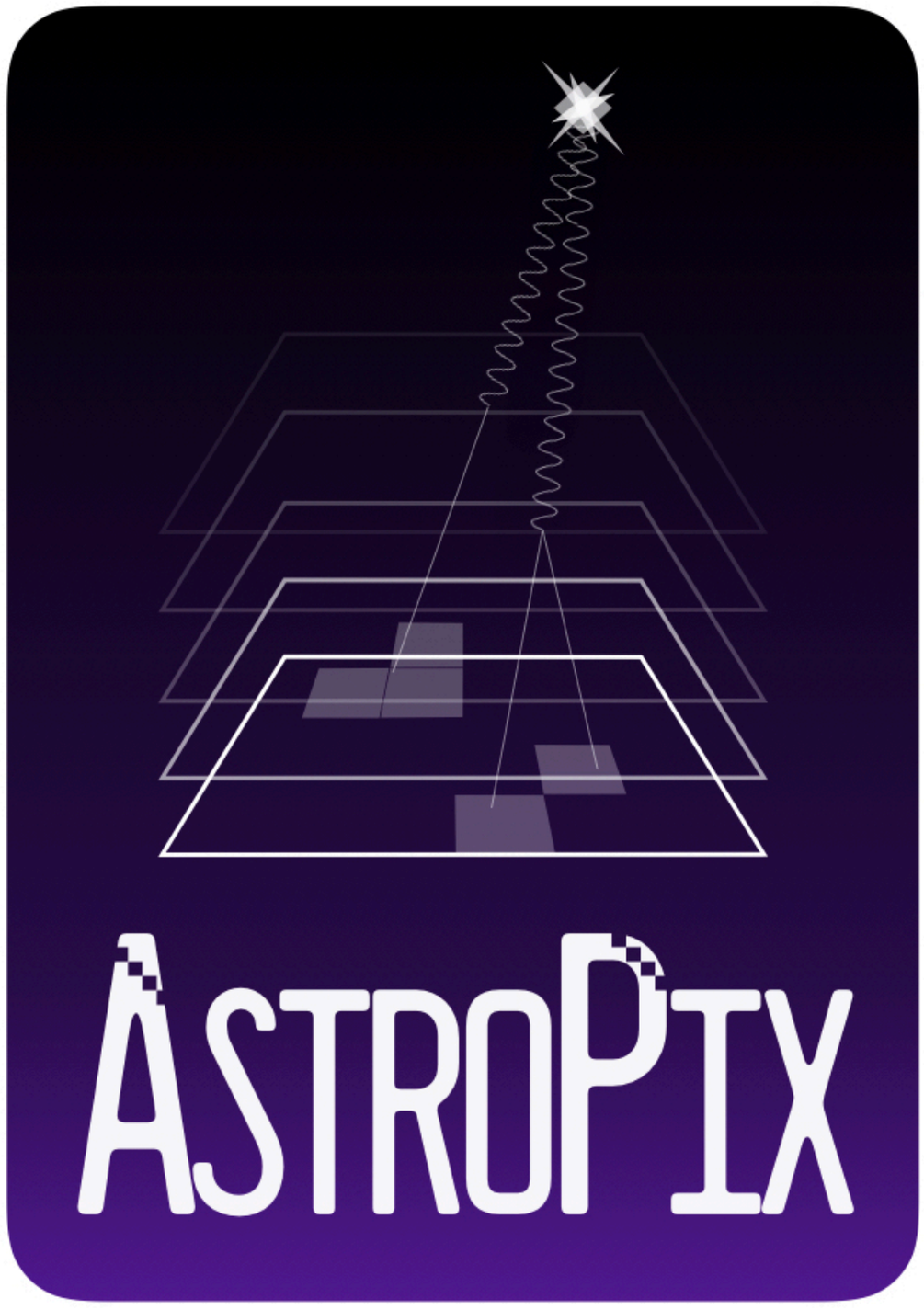

AstroPix: Investigating the Potential of Silicon Pixel Sensors in the Future of Gamma-ray Astronomy

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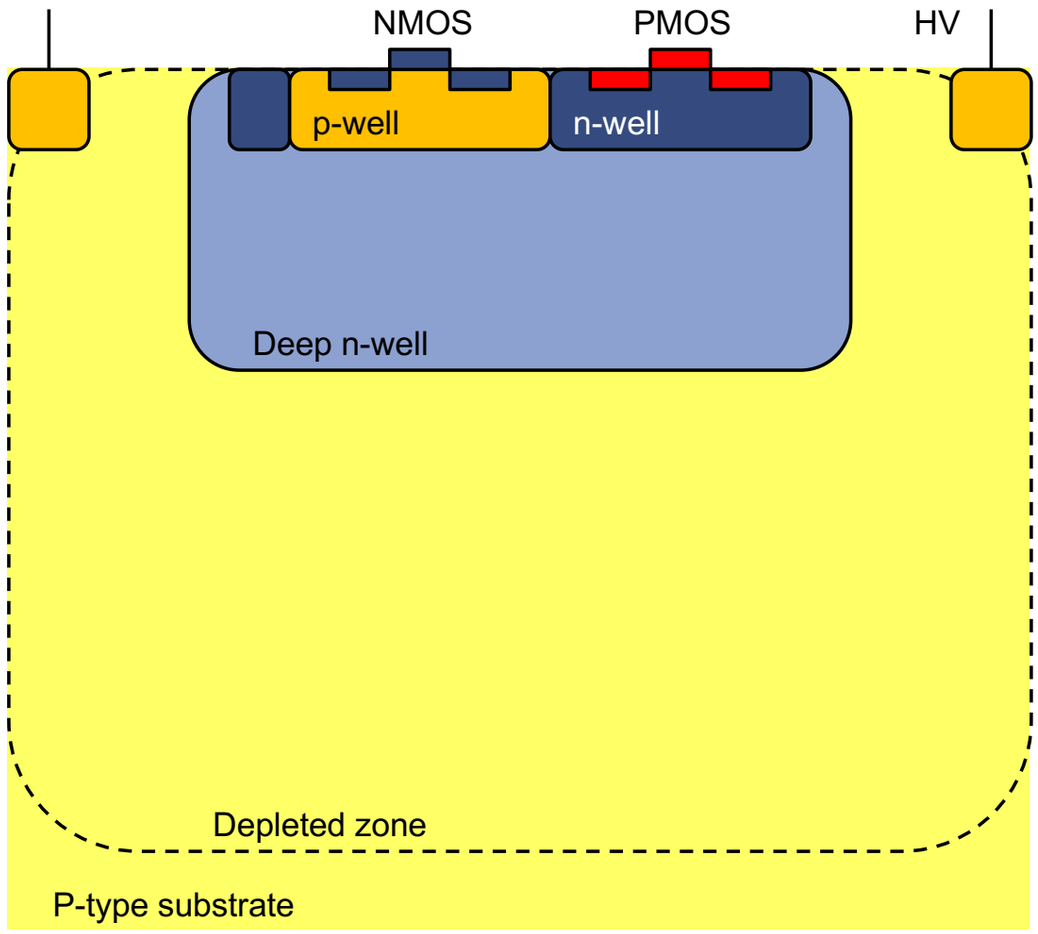
Argonne NATIONAL LABORATORY

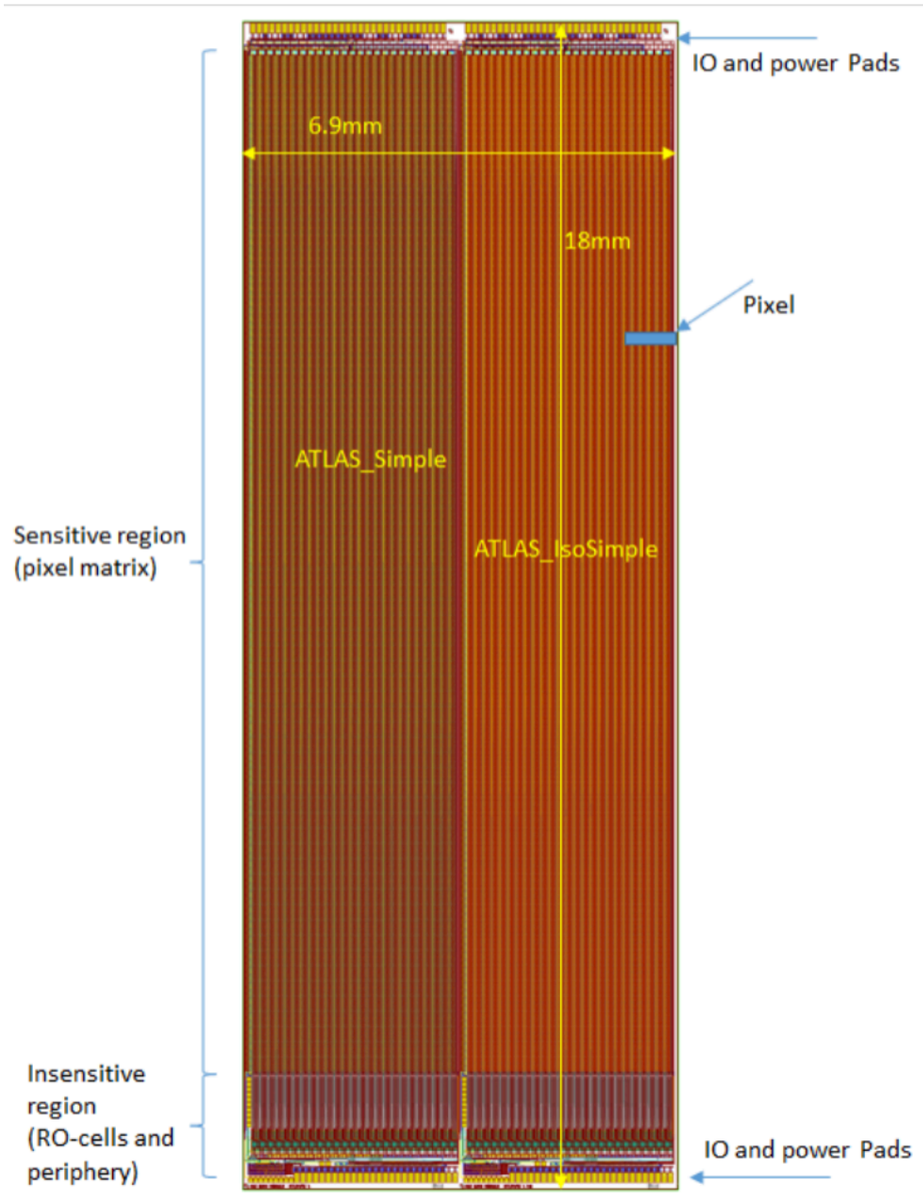
NASA

CMOS

- **Complementary Metal-Oxide-Semiconductor (CMOS)** is a common fabrication technique used in commercial industry.
  - Mass produced —> low cost!
  - Pixelated silicon sensors use High Voltage CMOS manufacturing processes to co-integrate detector and readout electronics.
    - Saves on space, power requirements
    - Less noisy



ATLASPix



Two ATLASPix detectors side-by-side [2].

- Built and optimized for the CERN experiment ATLAS.
  - Optimized for Minimizing Ionizing Particles (MIPs):
    - Radiation hard, oblong pixels.
    - Fast timing resolution of 25 ns, low digital energy resolution of 6 bits.
- Monolithic silicon pixels, each pixel 50 µm by 140µm and 100 µm thick.
  - Four matrices, each matrix 25 by 100 pixels (x by y).
  - We're using the same hardware to communicate to the device as was used at CERN and collaborators at CERN provided baseline measurements for our tests.

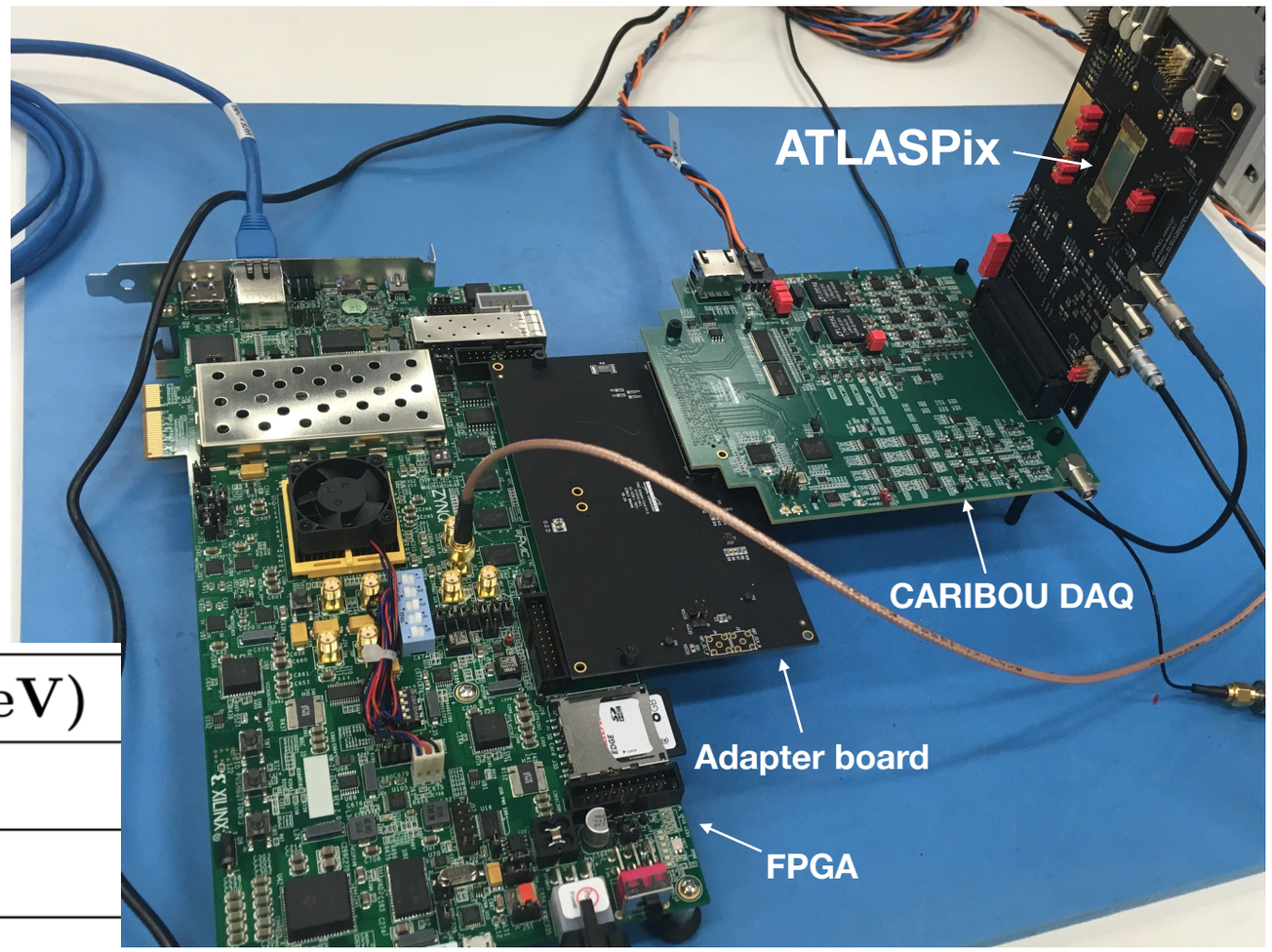
AstroPix Requirements

Parameter	Goal
Energy Resolution	<2% at 60 keV, 10% at 60 keV required
Power Usage	~3 mW/cm^2
Passive Material	<5% on the active area of the silicon
Pixel Size	500 um
Silicon Thickness	500 um
Time Tag	~ 1us
Position Resolution	~250 um

Experimental Setup

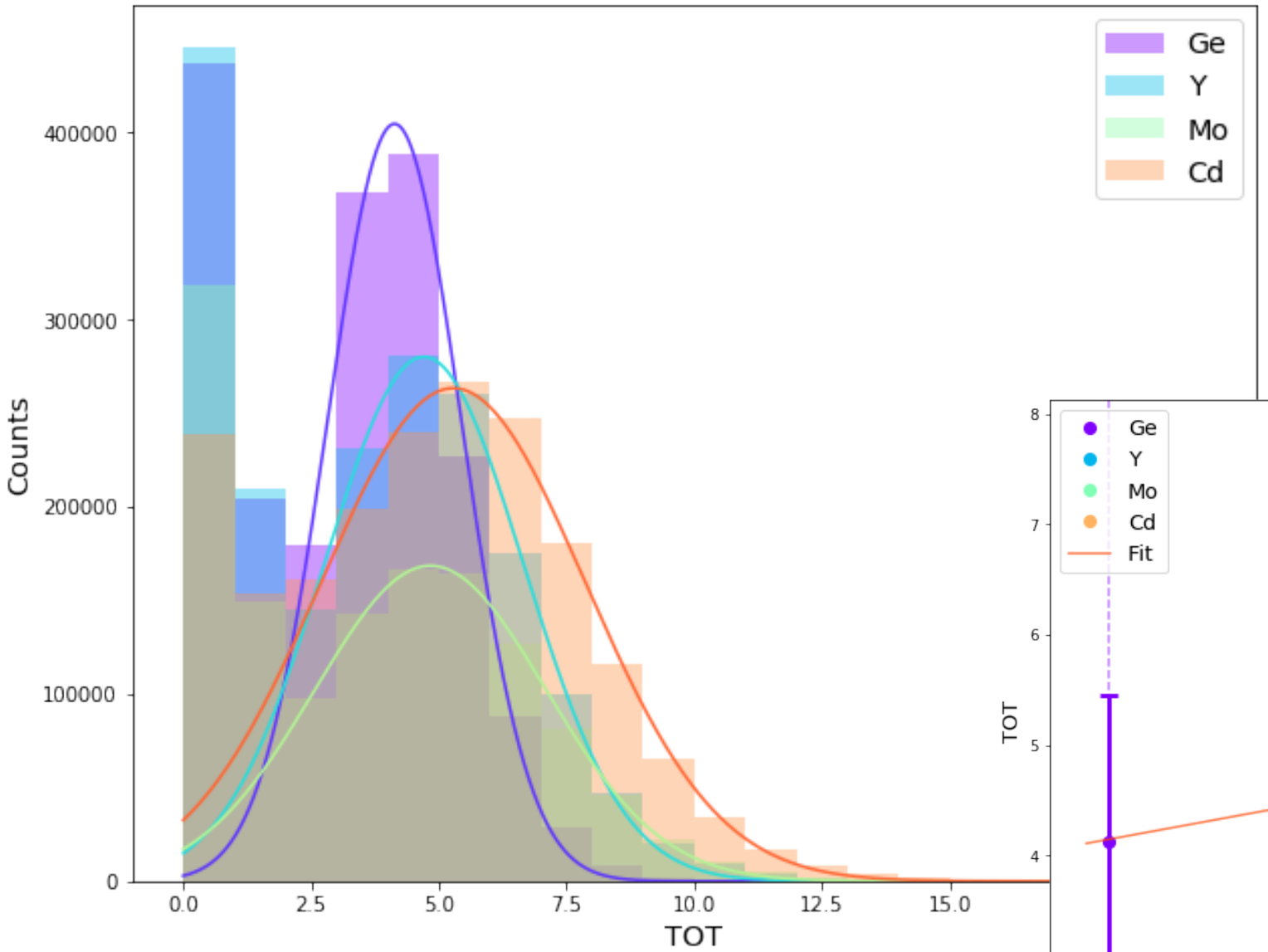
- Radioactive sources were chosen based on the current dynamic range of the detector (~5 keV to 33 keV)
- Dynamic range limited by the current thickness of Si

Source	Energy (keV)
Fe55	5.89
Ge	9.89
Y	14.96
Mo	17.5
Cd109	21.99
Ba133	30.97



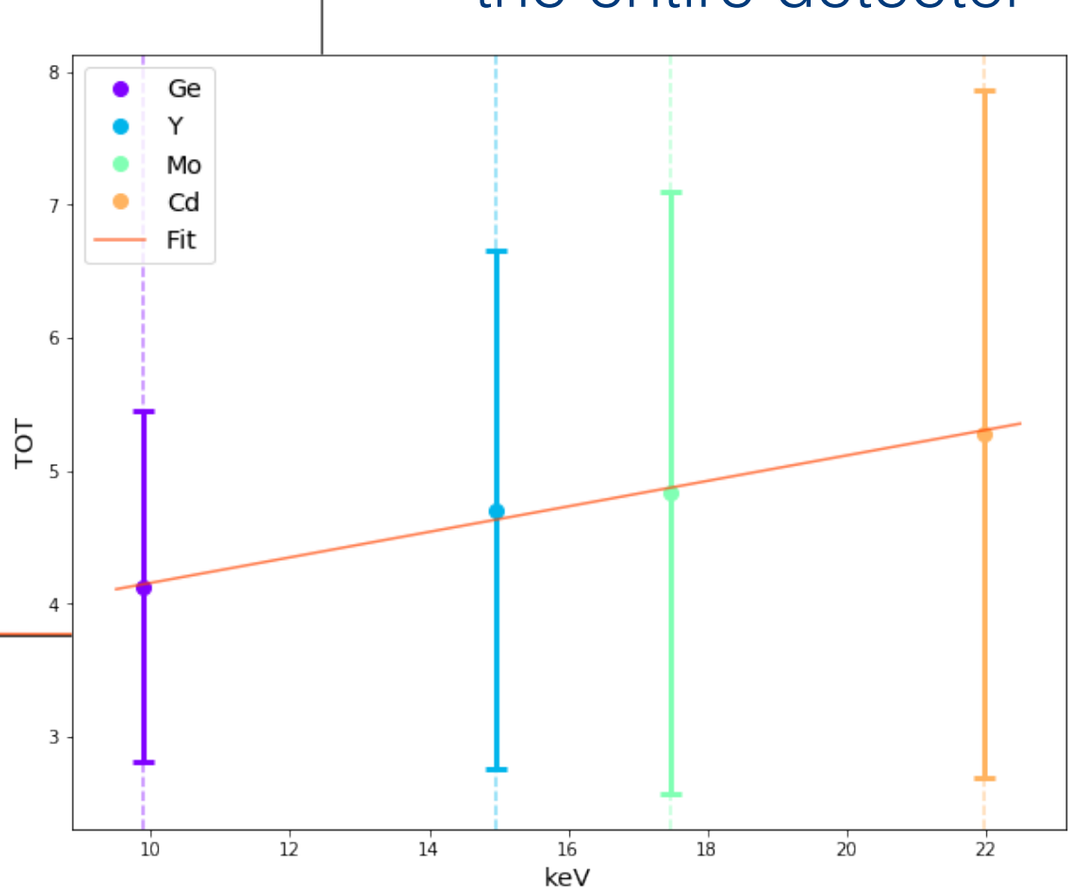
Bench top setup for ATLASPix

Digital Energy Calibration



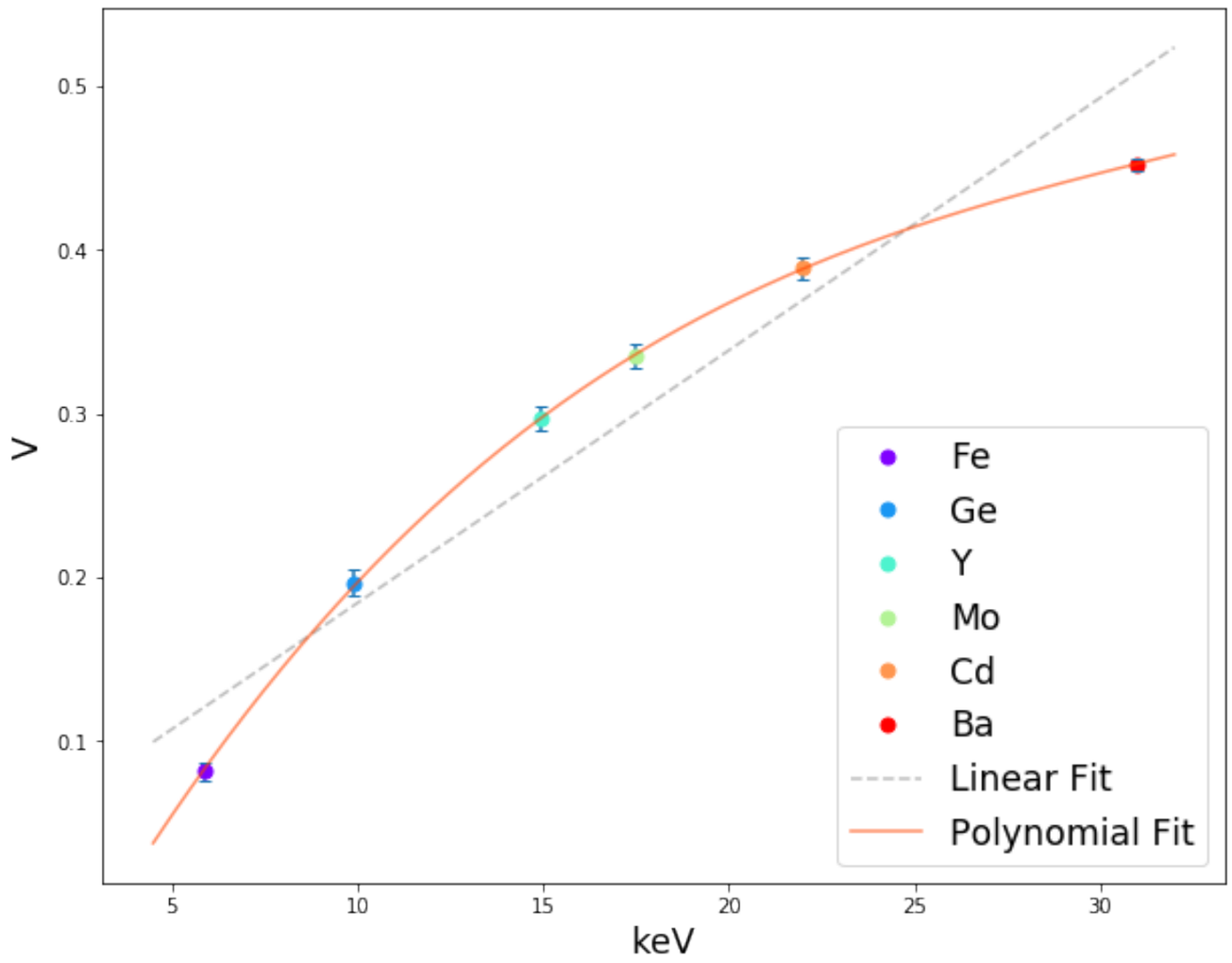
TOT = Time Over Threshold

TOT photopeaks represent TOT hits from individual pixels, with pixels used from across the entire detector

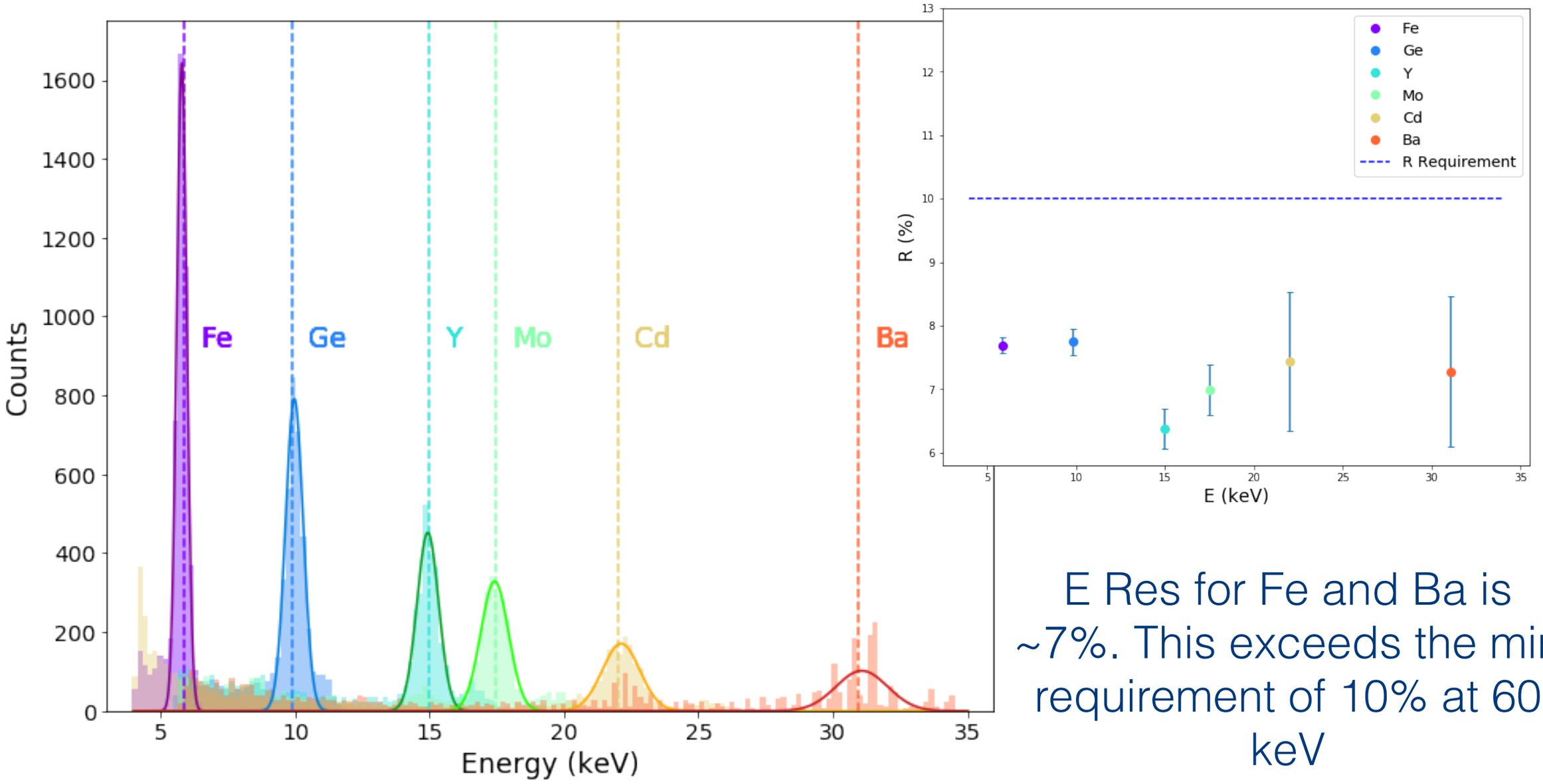


Analog Energy Calibration

- Calibration relates the found peak position in V at each source and energy and the theoretical energy value in keV.
- The detector response is non-linear, this isn't surprising
- A three-degree polynomial was found to best represent the detector response



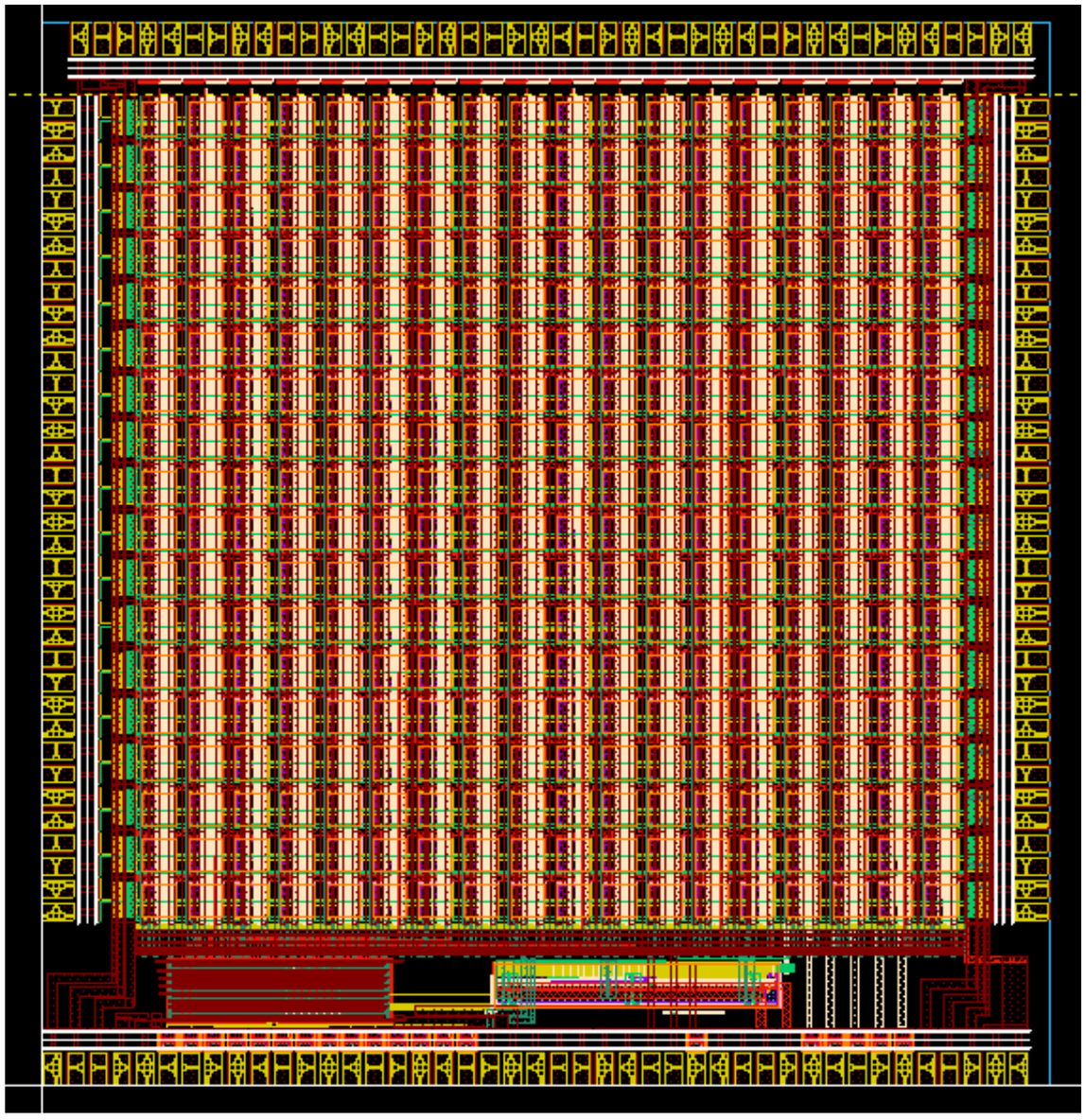
Analog Energy Resolution



E Res for Fe and Ba is ~7%. This exceeds the min requirement of 10% at 60 keV

AstroPix V1

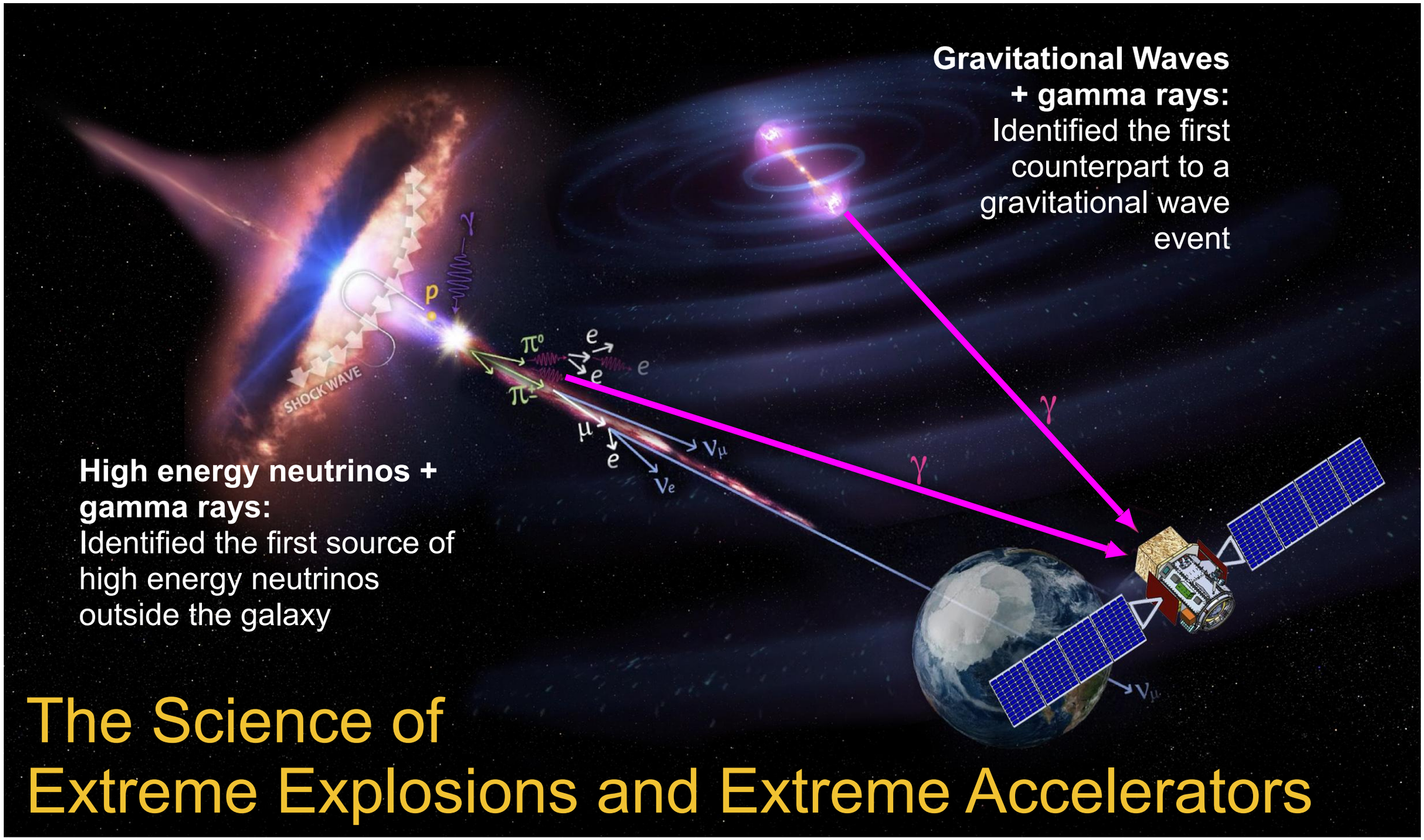
- Pixel
  - 165x165 μm active pixel area, 200 μm pitch
  - Read out by connecting to both row and column
- Matrix
  - 4.5 x 4.5 mm chip area
  - 18 x 18 pixel matrix
- Digital Periphery
  - Time stamp counters for each row and column
- Other
  - 36 analog/comparator outputs



R. Leys and I. Peric

AMEGO-X and Multimessenger Astrophysics

Gamma-ray observations played the critical discovery role in *all* major multimessenger discoveries in the past half decade



Summary and Next Steps

- Analog energy resolution of ATLASPix, a driving parameter for AstroPix, is encouraging

- Digital resolution needs to be redesigned; we can borrow from the functionality currently devoted to timing resolution

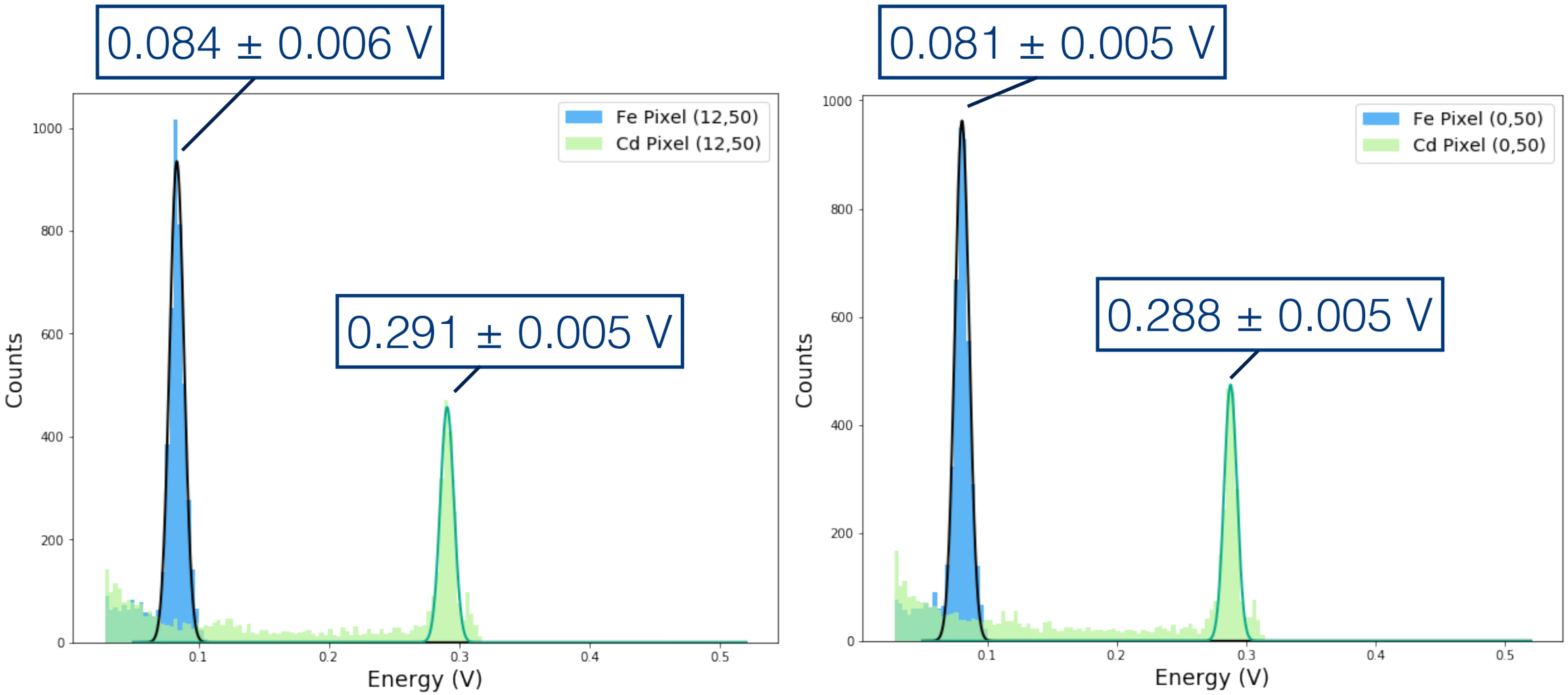
- AstroPix V1 has been fabricated and is about to undergo testing

- Promising start to monolithic Si in the future of gamma-ray astrophysics

References

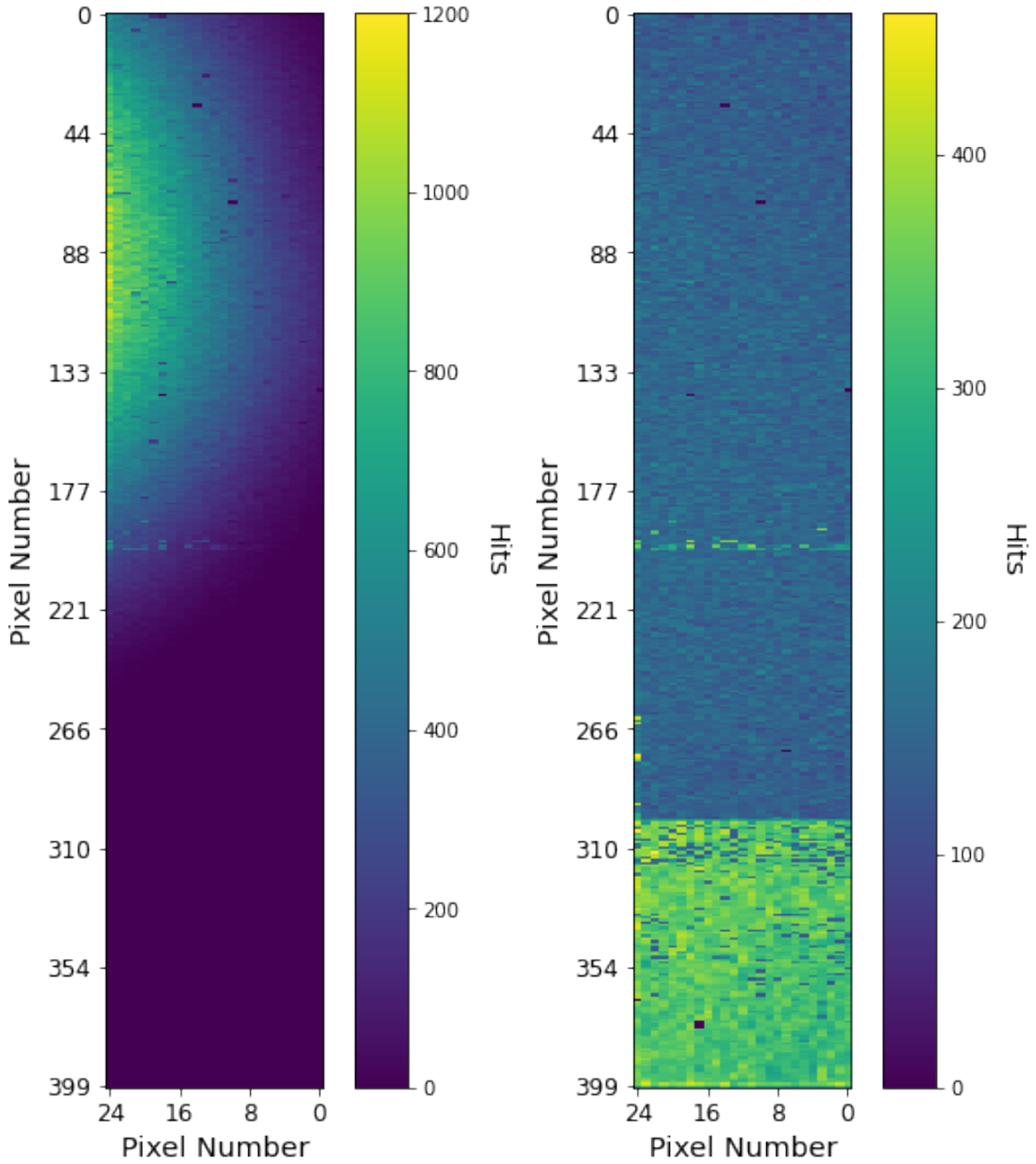
1. Caputo, R. and et al., “Astropix: Developing Silicon Pixel Detectors for Gamma-ray and Cosmic-ray Astrophysics.,” APRA Proposal: Submitted in response to NNH18ZDA001N-APRA: D. 3 Astrophysics Research and Analysis (2018).
2. McEnery, J., Barrio, J. A., Agudo, I., and et al., “All-sky Medium Energy Gamma-ray Observatory: Exploring the Extreme Multimessenger Universe,” Bulletin of the American Astronomical Society Vol.51, Issue7, 285–320, 363–376 (2019).
3. Peric, I., Prathapan, M., Zhang, H., Weber, A., and Messaoud, F. G., “Description of the ATLASPixsimple and ATLASPixm2, Preliminary v2.”
4. Schoning, A., Anders, J., Augustin, H., Benoit, M., Berger, N., Dittmeier, S., and et al., “MuPix and ATLASPix – Architectures and Results,” arXiv(2020).

Analog Output of ATLASPix



Histograms of the raw analog data (in volts) from two pixels. The same two sources, Fe55 and Cd109, were used. Left: Pixel (12,50). Right: Pixel (0,50).

Hit Distribution



- Heatmaps of the ATLASPix detector showing the distribution of hits when the detector is exposed to radioactive sources.
- Both axes represent pixel number in the x and y direction respectively. Data was extracted from the digital DAQ file, which records x and y position of each hit.
- Left: Fe55, Right: Cd109